NASA-CR-200074

Progress Report

Contract NASW-4803 **Dynamics of Superfluid Helium in Low Gravity**

Principal Investigator David J. Frank
Contract period of performance June 1994-December 1995
Report date December 1995

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Contract objective

The objective of this contract is to perform low-gravity verification tests of a computational fluid dynamics (CFD) program that incorporates the two-fluid model of superfluid helium (SFHe). This will be accomplished by flying a SFHe dewar on the NASA DC-9 Low Gravity Aircraft and recording the slosh motion of the SFHe using a video camera. The acceleration environment will also be recorded for use as an input to the CFD code. The observed motion will be compared to the motion predicted by the CFD code. Verification of the accuracy of the code will aid in the design of future satellites carrying SFHe such as SIRTF, the Relativity Mission (GP-B) and other planned orbital helium systems.

Progress

1) Cryogenic Test Apparatus

During this last performance period, considerable progress had been made. The fabrication, assembly, and test of the dewar have been completed. The dewar was shipped to the NASA Jet Propulsion Laboratory (JPL) at the end of October along with it's safety document. The dewar is presently being integrated into the JPL "Low Gravity Float Package". Full up systems test are expected to begin the second week of January 1996. The flight is planned for the week of January 29th at NASA/Lewis. The dewar, the JPL Float Package, and the ground support equipment is presently planed to be shipped from JPL to NASA/Lewis the week before flight.

Prior to shipping the dewar to JPL, it successfully completed it's acceptance and proof pressure tests. The acceptance test characterized the helium boil-off rate, verified the vacuum integrity at superfluid helium temperature and verified the temperature thermometry. The accuracy of the temperature sensors was verified by measuring the lambda point of the superfluid helium.

A schematic of the dewar is shown in figure 1 and photos of the helium tank and the entire dewar are shown in figures 2 and 3. The results of the hold time testing is shown in figure 4 which shows that the boil-off rate is low enough to carry out the test during the two hours of flight. It is noted that the dewar is initially filled with normal boiling point (NBP) liquid helium at one atmosphere and subsequently pumped down to superfluid helium condition. During this pump-down 50 percent of the helium is evaporated which results in a tank half full when the test is started. Designing the dewar for subatmospheric top-off is considerably more complex and beyond the scope of the project.

Peter Mason (JPL Technical Monitor) and myself visited NASA/Lewis to review the experiment with the DC-9 Low Gravity organization. This will be the first time that this organization will be flying a cryogenic experiment and was very interested in the potential hazards. Due to the servicing aspects of cryogens and the limited hold time of the superfluid helium we requested some unique servicing windows prior to flight. The NASA/Lewis personnel were very cooperative. During our visit, we took the opportunity to fly the aircraft to get familiar with the operations.

A number of slosh tests were carried out in one gravity in the laboratory to characterize the fundamental frequency and damping. Results of these tests are shown in figure 5. It is worth noting that the slosh frequency follows the well establish models developed for storable fluids based on the depth of the settled liquid.

2) Computational modeling

Computational modeling using both the base FLOW3D code and the SFHe3D two-fluid superfluid helium code have begin. The codes are being used to model the fluid's motion as a result of a disturbance. Some typical results are shown in figures 6 and 7 which show the zero gravity predicted motion of the fluid's center of mass due to a 1 second disturbance of 1 mg for fill fractions of 40 and 28 percent respectively computed by both the single and two fluid models. Unfortunately the slosh frequency is predicted to be so low that verification in the 20-30 second period in the low-gravity aircraft will be difficult. Disturbing the fluid with a larger impulse that will generate a slosh frequency within the available test time results in a fairly violent motion of the fluid. An example is shown figure 8 which shows the fluid motion due to a 5 mg disturbance in zero gravity as predicted by the single fluid model.

The simulations that have been run to date are being used to plan the type of tests that will be performed. In addition to the near zero gravity tests I hope to run a few cases at an intermediate background gravity field. Figure 9 shows a two fluid model prediction of fluid motion at 0.02 G gravity.

The computer simulations of the one-G tests are progressing with the main enphisis now on being able to compute the actual damping of the fluid. These computer runs will establish the required modelling parameters (such as computatinal grid size) that are required.

As soon as the flight takes place and the data is reduced, the simulations of the actual test runs will be made.

Remainder plan

The following plan will complete this project. The experiment will be carried out at the end of January with the data reduction to take place during the months of February and March. Once the data is reduced, the computational task of modeling will take place.

January 1996	System test of experiment and JPL Float Package
Jan./Feb. 1996	Flight at NASA/Lewis
March 1996	Completion of flight data reduction
October 1996	Completion of project and final report

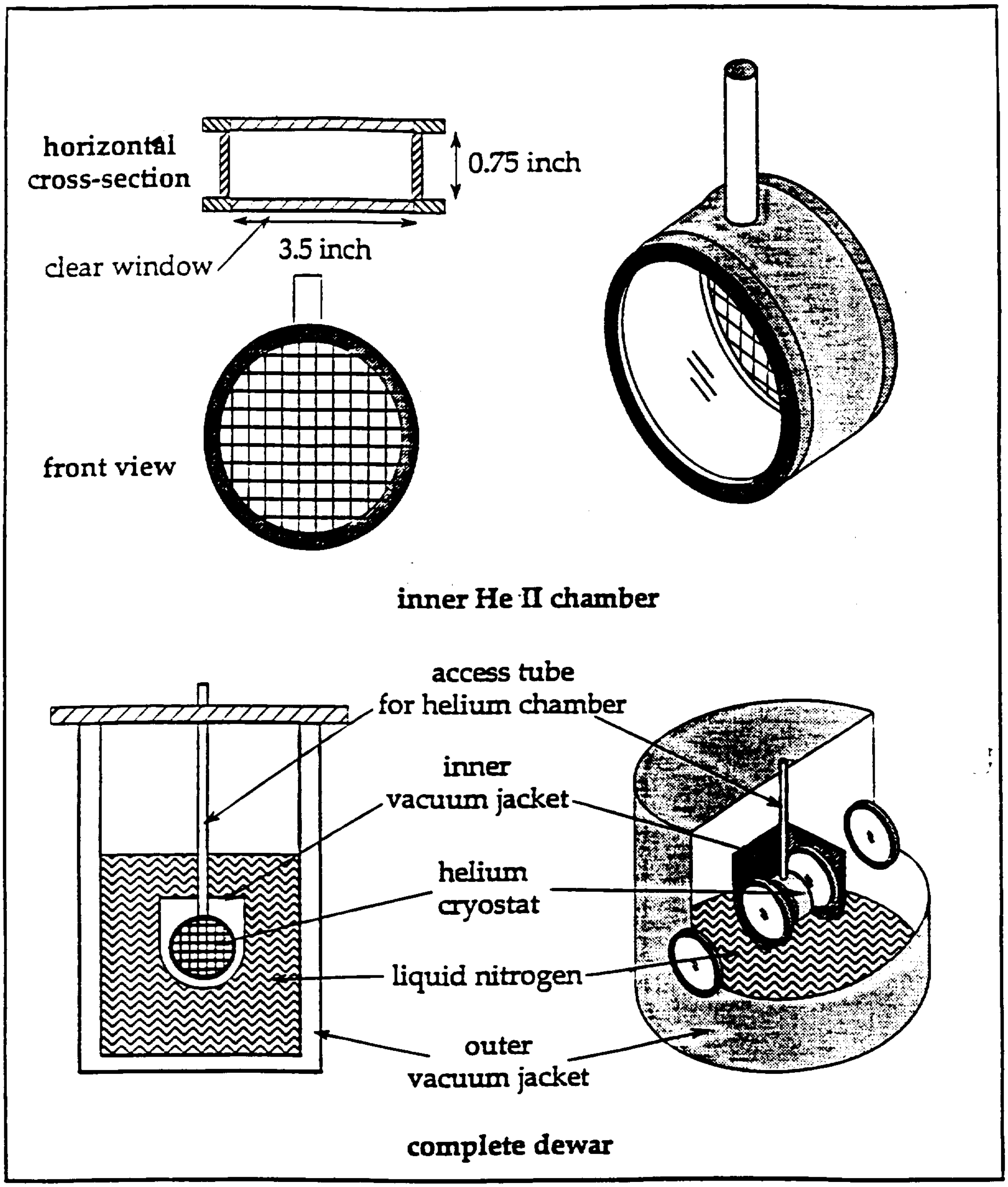


Figure 1: He II Dewar.

This figure shows the dewar. There is an inner chamber that contains the He II. This chamber is inserted into a small vacuum jacket which is then submersed in a liquid nitrogen bath, as shown in the lower portion of the figure. The outer vacuum jacket has windows on each side in line with the windows of the inner dewar.

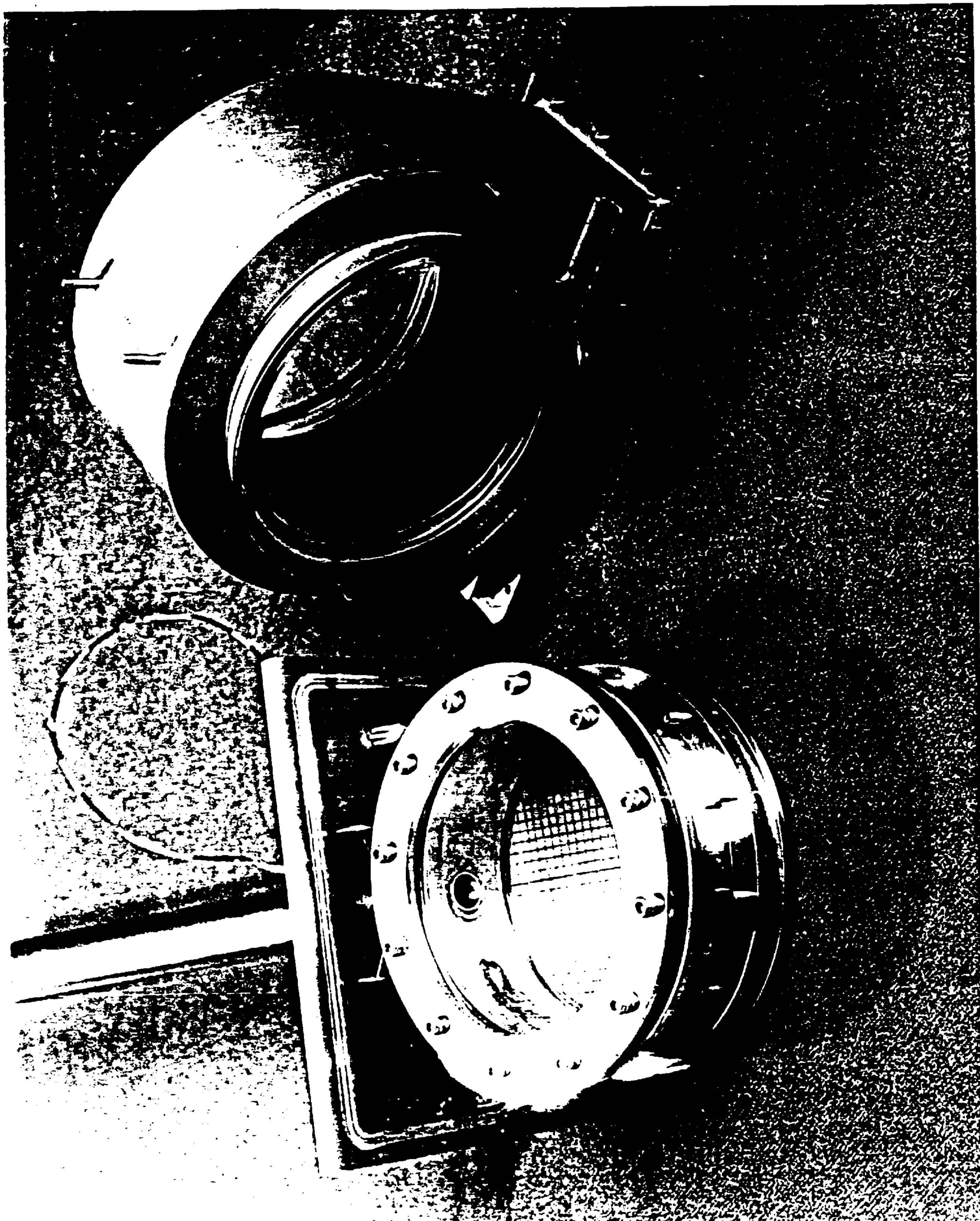


Figure 2: Inner He II Chamber.

'his figure shows the inner He II chamber and it's vacuum jacket.

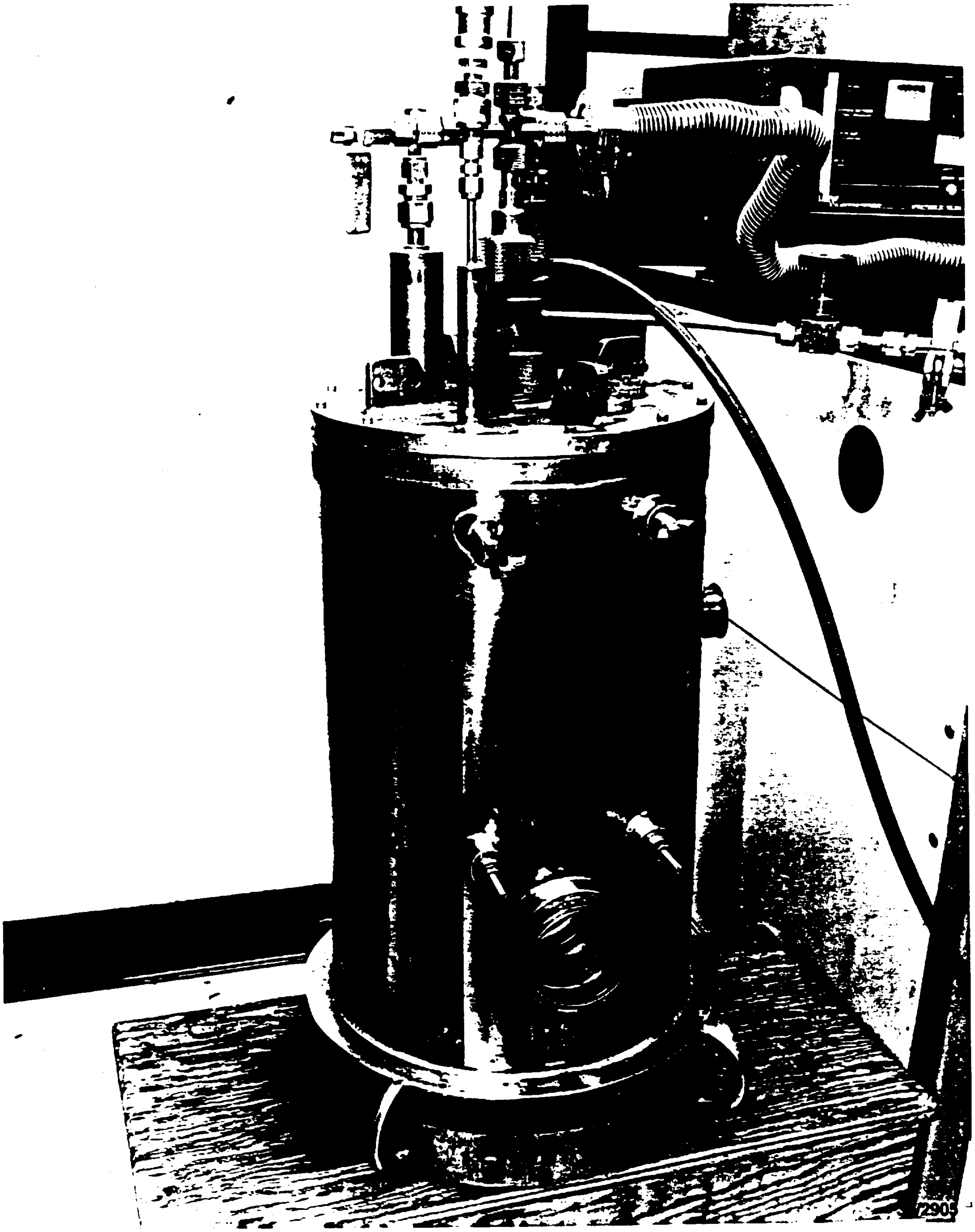


Figure 3: Competed Dewar.

This figure shows the completed dewar without the Ground Support Equipment and the JPL Low Gravity Float Package.

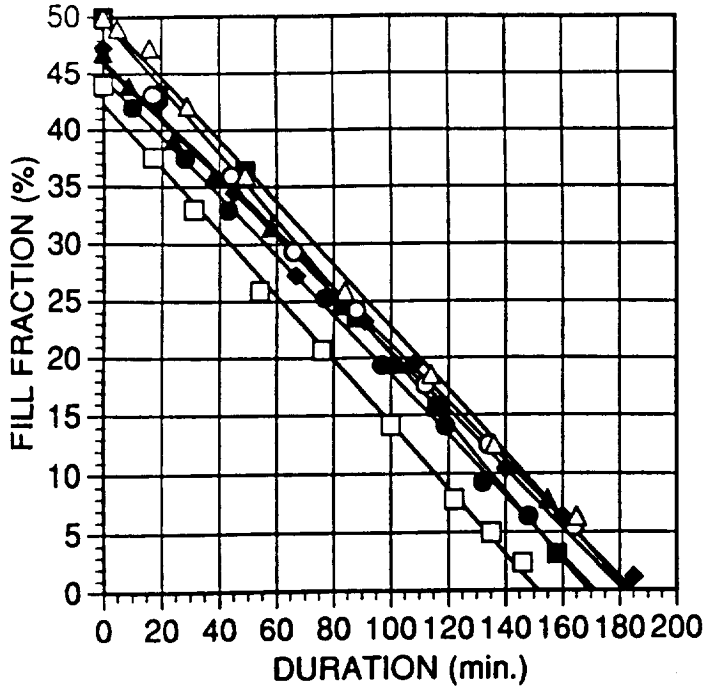


Figure 4: Helium boil-off data.

This figure shows the remaining amount of liquid helium in the He II chamber after it has been pumped down to 1.7K. 50 percent of the liquid is lost in the pump-down from normal boiling point (4.2K).

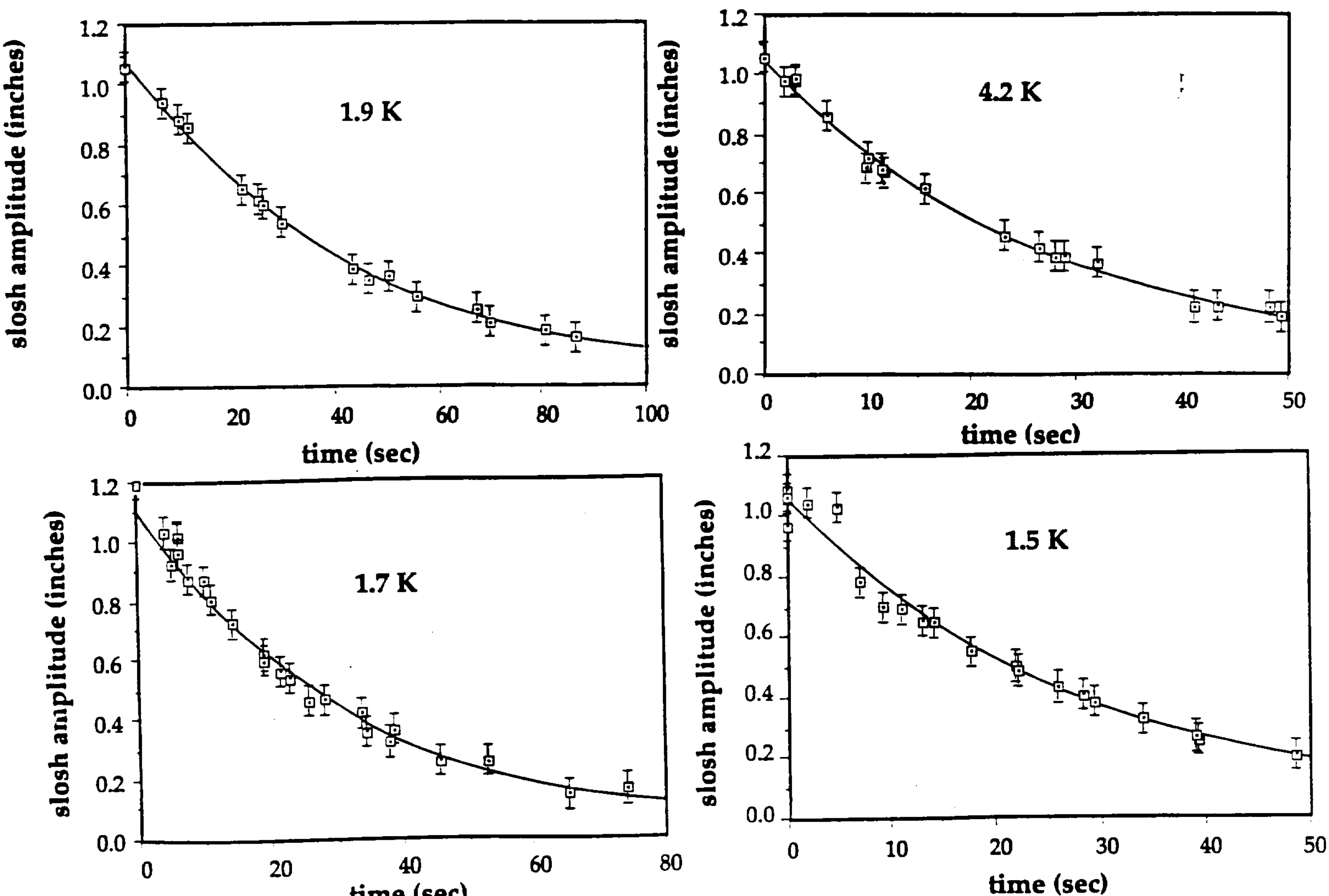
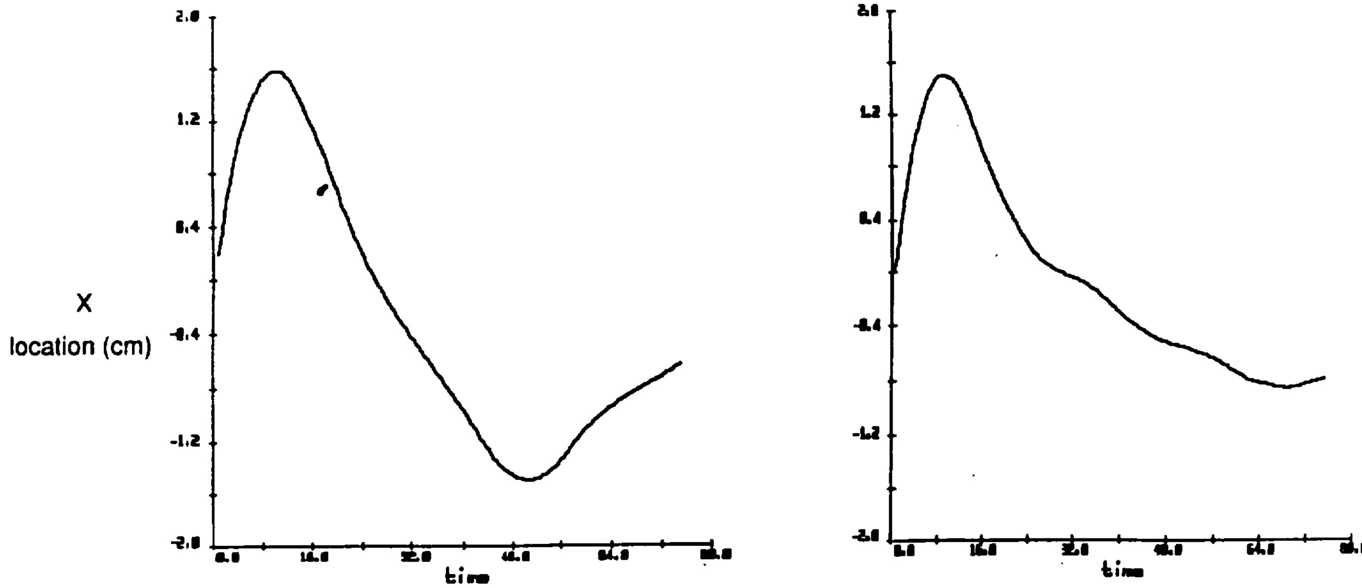


Figure 5: One Gravity Slosh Decay Data.

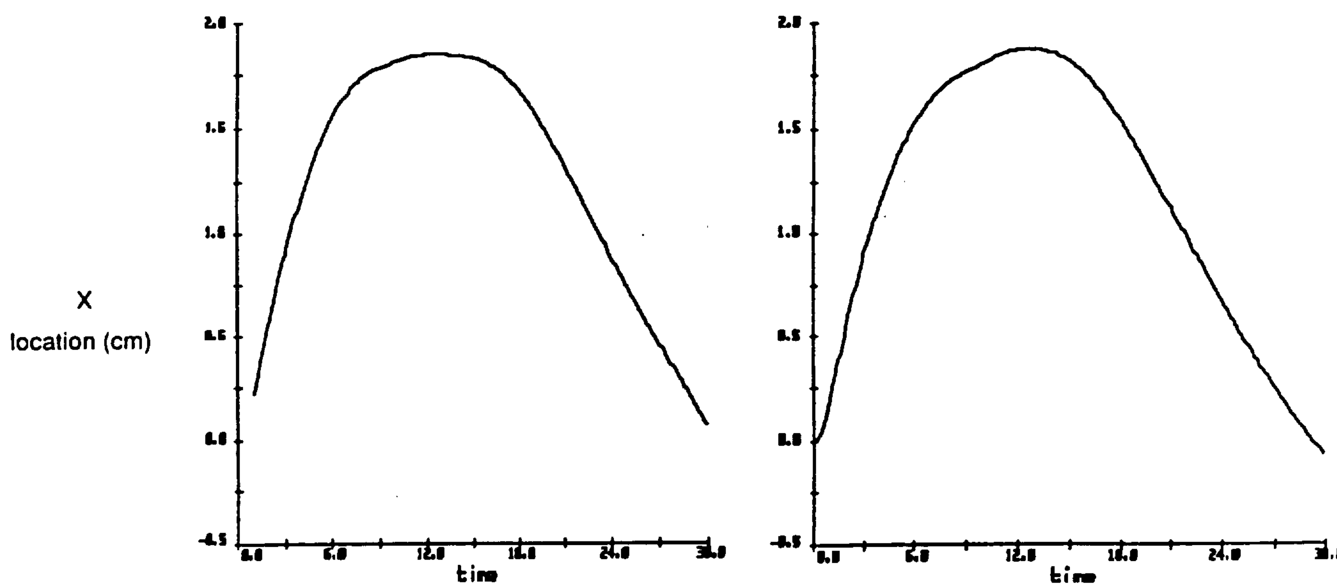
This figure shows some of the data taken on the slosh amplitude decay of the helium for different temperatures in one gravity. The data was measured a approximately one inch from the center of the chamber. The chamber is near half full.



Single Fluid model **Two Fluid model**

Figure 6: Zero Gravity Center of Mass displacement-40% fill level, 1 mg-sec disturbance

This figure shows the history location of the center of mass of the He II (1.7K) due to a lateral disturbance of 1 mg-sec predicted by the single and two fluid models. The fill level is 40 percent. Results show a slightly higher damping effect of the two fluid model.



Single Fluid model **Two Fluid model**

Figure 7: Zero Gravity Center of Mass displacement-28% fill level, 1 mg-sec disturbance

This figure shows the history location of the center of mass of the He II (1.7K) due to a lateral disturbance of 1 mg-sec predicted by the single and two fluid models. The fill level is 28 %. Results show no significant difference between the two models.

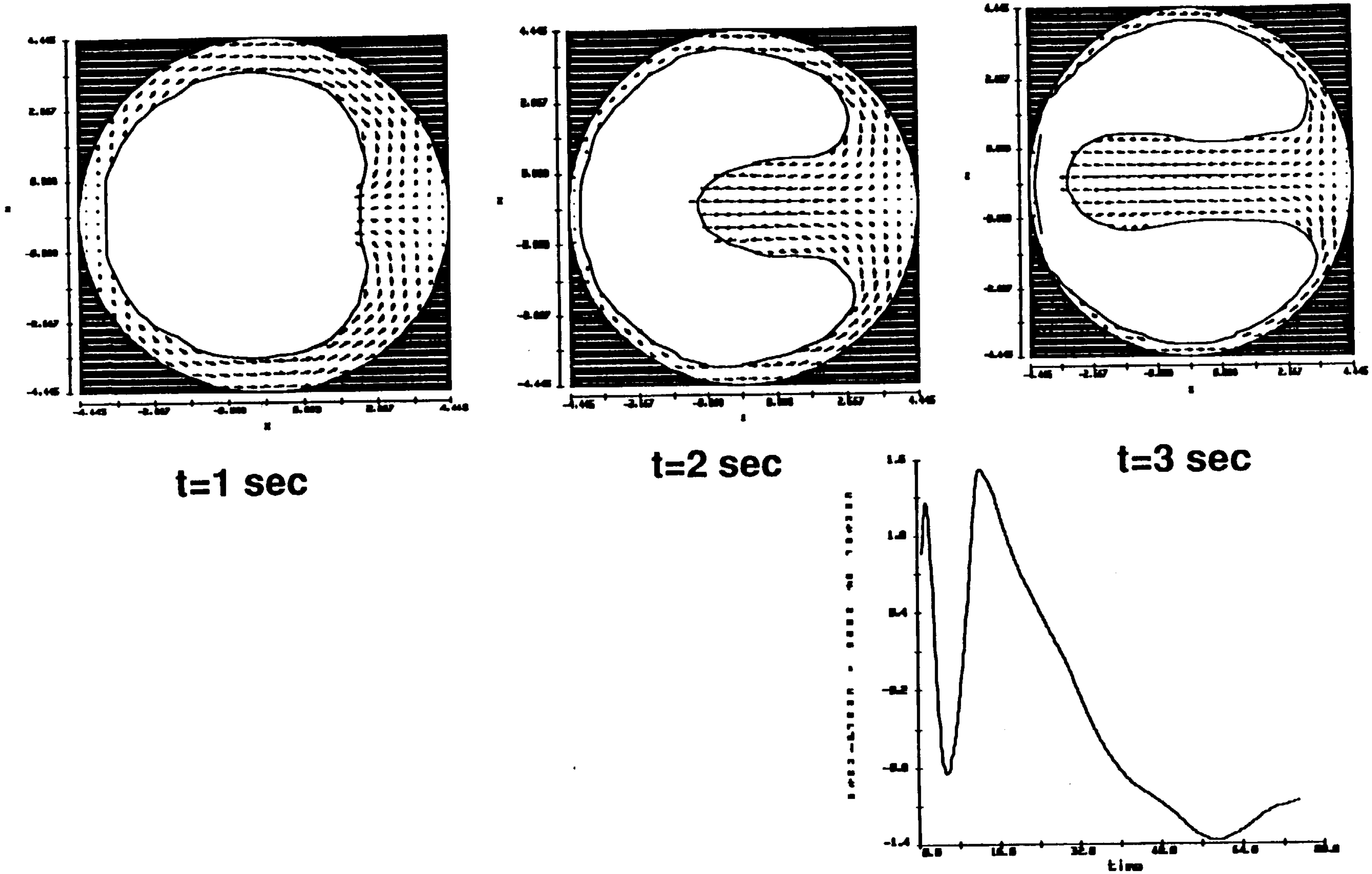


Figure 8: Zero Gravity Center of Mass displacement-40% fill level, 5mg-sec disturbance

This figure shows the history location of the center of mass of the He II (1.7K) due to a lateral disturbance of 5 mg-sec predicted by the single fluid model. The fill level is 40 %. Results show a fairly violent fluid motion with an initial slosh frequency within the available test time of the DC-9 Low Gravity aircraft..

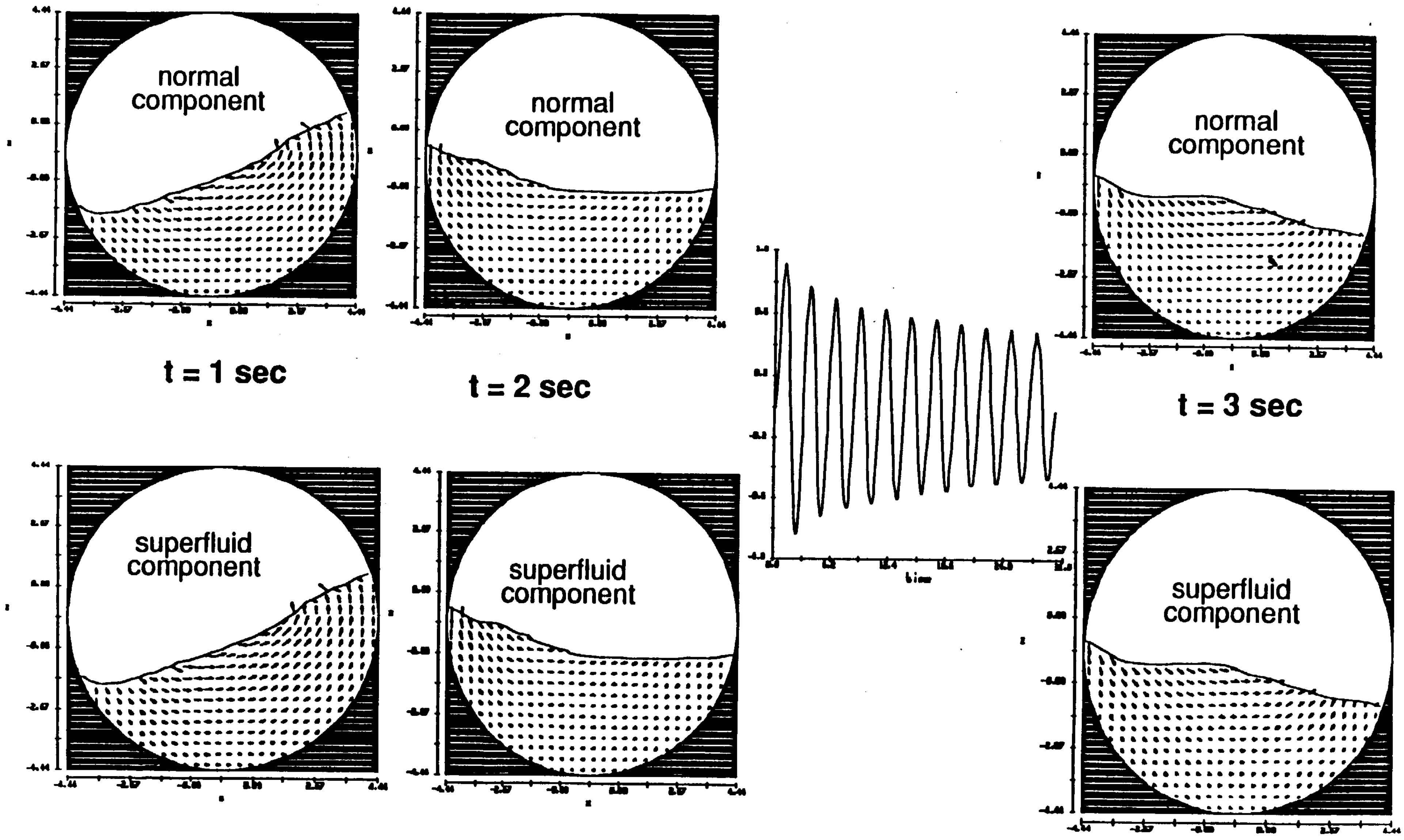


Figure 9: 20 mg Two Fluid Model Prediction- 41 % fill level, 5mg-sec disturbance

This figure shows the history of the fluid and center of mass of the He II (1.7K) due to a lateral disturbance of 5 mg-sec predicted by the Two Fluid model. The fill level is 41% and in a 20 mg gravity. The Bond number is large enough to keep the fluid settled. The plots of the velocity profile of the normal and superfluid components show that they are both in the same direction.